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NOISE ABATEMENT METHOD AND APPARATUS

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This invention relates to noise suppression and more particularly to the abatement of noises of discrete frequency emanating from rotating machinery utilizing rotating blades and stationary vanes and in particular from an inlet of an axial flow compressor of the type commonly used in aircraft gas turbine powerplants and from shrouded marine propellers.

With the advent of jet powered aircraft and, in particular, commercial jet aircraft entering and leaving municipal airports, the question of how to suppress the noise created by a jet engine has been given extensive consideration. The first problem attacked by engineers in this field was the reduction or elimination of exhaust gas wake noise. Both the use of the exhaust gas wake noise suppressors developed during this early period, for example of the type taught in our U.S. Patent Nos. 2,845,775, 2,930,185, 2,931,171, 2,936,846, 2,944,392, 3,027,713 and 3,033,494, and the advent of the turbofan type power plant with its reduced jet exhaust noise, brought more sharply to the public's attention the discrete frequency noise, sometimes called "whine," generated by the compressor and being propagated groundwardly, mainly from the compressor inlet. This compressor inlet whine is most objectionable during municipal airport approach when the jet engines of the aircraft are operating at reduced power and hence the jet exhaust noise is greatly reduced. The "whine" is not so objectionable at take-off for the jet exhaust noise then conceals it. It had been thought that the compressor inlet discrete frequency noise was akin to the type of noise generated by an aircraft propeller. When the existing knowledge regarding propeller noise was applied to solve the compressor inlet discrete frequency noise problem, predicted results were at great variance with actual measurements. These discrepancies were left with the status of unresolved paradoxes and it has become clear that aircraft propeller generated noise and compressor generated discrete frequency noise could not be similarly explained.

Equally important is the problem of supressing the noise made by marine propellers on naval vessels. During an attack upon a submarine, the surface vessel can detect the position of the target submarine from the noise made by its propellers and if the target submarine should have to discontinue the use of its propellers in order to avoid or eliminate the noise made thereby, it would be impossible for the target submarine to escape from the attack area. In addition, attacking submarines are aided in detecting the whereabouts of surface vessels by the surface vessel propeller noise. It is, therefore, important for both surface and submarine naval vessels that their propeller noises be eliminated or drastically reduced. We have found that since both air and water are fluids, they have similar wave transmission characteristics. The propagation of acoustic energy through air is similar in considerable detail to the propagation of hydrodynamic pressure waves through water.

While the description of our invention will be made using an axial flow compressor of an aircraft turbojet engine as the primary illustration, it should be borne in mind that the principles taught herein are equally applicable to shrouded marine propellers and other types of rotary machinery using rotating blades and stationary vanes or struts.

We have made extensive studies and experimentations

regarding axial flow compressor inlet discrete frequency noises and have found, as more fully described hereinafter, that they comprise spinning modes or rotating pressure fields caused both by the revolving compressor rotor blades by themselves and by the interaction established between adjacent rows of compressor rotor blades and compressor stator vanes.

It is an object of this invention to provide method and apparatus for reducing and eliminating discrete frequency noises, both fundamental and harmonic, generated in an axial flow compressor and which emanate from the compressor inlet and/or discharge.

It is a further object of this invention to teach method and apparatus for reducing the discrete frequency noise emanating from an axial flow compressor comprising selecting blade and vane combinations which are of such number and so positioned relative to one another that either a reduced strength spinning mode is formed, or a spinning mode is formed of such a nature that it will not be propagated through the compressor duct and out through the compressor inlet and/or discharge but, in fact, will decay within the compressor duct, or such that spinning modes of equal intensity and opposite phases are generated or established so they will cancel each other within the compressor duct, or such that the radiation directivity pattern of the discrete frequency noise emanating from the compressor inlet produces reduced exposure time to those on the ground as the airplane flies by overhead, or such that the modes which propagate from the compressor inlet are established at a sufficiently high frequency to be above the range of high human hearing sensitivity; namely, 7,000 c.p.s. (cycles per second).

It is still a further object of this invention to select the number of blades in rotors of an axial flow compressor and to select the number of vanes in stators of an axial flow compressor and to axially position the rotors and stators such that the spinning modes created by rotor-stator interaction are substantially equal, then indexing the rotors and stators circumferentially to cause the equal amplitude spinning modes to be out of phase and hence cancel.

It is still a further object of this invention to select blade-vane combinations in an axial flow compressor such that the number of vanes is approximately equal to or greater than twice the number of blades times the number of the harmonic index of the discrete frequency noise being considered.

It is still a further object of this invention to teach a method and means of reducing discrete frequency compressor inlet noises comprising choosing blade-vane combinations such that the spinning modes created have a minimum of approximately 8 lobes.

It is a further object of this invention to teach a method and means of reducing the discrete frequency compressor inlet noise in an axial flow compressor comprising selecting a blade-vane combination to produce a spinning mode having m number of lobes wherein m equals the harmonic index n, times the number of blades, B, plus an independent positive or negative integer, k, times the number of vanes, V, and so that the number of lobes, m, is equal to or greater than the number given by the formula

$$nB(M_B \div M^*_m)$$

where M_B is the rotor circumferential tip Mach number and M^*_m is a cutoff or critical Mach number.

It is a further object of this invention to teach means and apparatus for producing a quiet compressor which means and apparatus comprise a system which is flexible and comprehensive and includes five basic courses of action which may be used, singularly or in combination, for controlling compressor noise.

Other objects and advantages will be apparent from the